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## GEOLOGICAL DESCRIPTION AND EFFECTS OF STRIP MINING ON COAL OVERBURDEN MATERIAL<sup>1</sup>

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Coal is a prime energy resource. Mining of coal has evolved from humble beginnings of hand mining with pick, shovel, and basket to the highly complex industrial operation of mechanized mining today. Mining in Ohio has gone through a series of changes and will continue to evolve as cheaper methods of mining are developed and remote resources of coal are sought.

Every type of coal mining has some effect on the rocks adjacent to the mined strata, but strip mining has the greatest effect. The effects may be physical, chemical, or a combination of these. Strip mining profoundly changes the physical and chemical character of the overburden rocks by breaking up the strata and intimately intermixing the various rock types in spoil banks. Thus chemical reactions take place between different rock types and between the rocks and the atmosphere. Most coal-bearing rocks were laid down originally as sediments in reducing environments, and when exposed today in a strip-mining operation, many of these rocks are placed in an oxidizing environment for the first time since their formation. It is the purpose of this paper to describe the general geology of the coal-bearing region of Ohio and to relate the geology to some of the physical and chemical changes that affect overburden material in strip-mine spoil banks.

### STRATIGRAPHIC DISTRIBUTION OF COAL BEDS IN OHIO

Coal-bearing rocks occupy the southeastern third of Ohio and cover about 9,000 square miles. These rocks belong to the Pennsylvanian and Permian Systems and, in the northern Appalachian region (fig. 1), are remarkable for their

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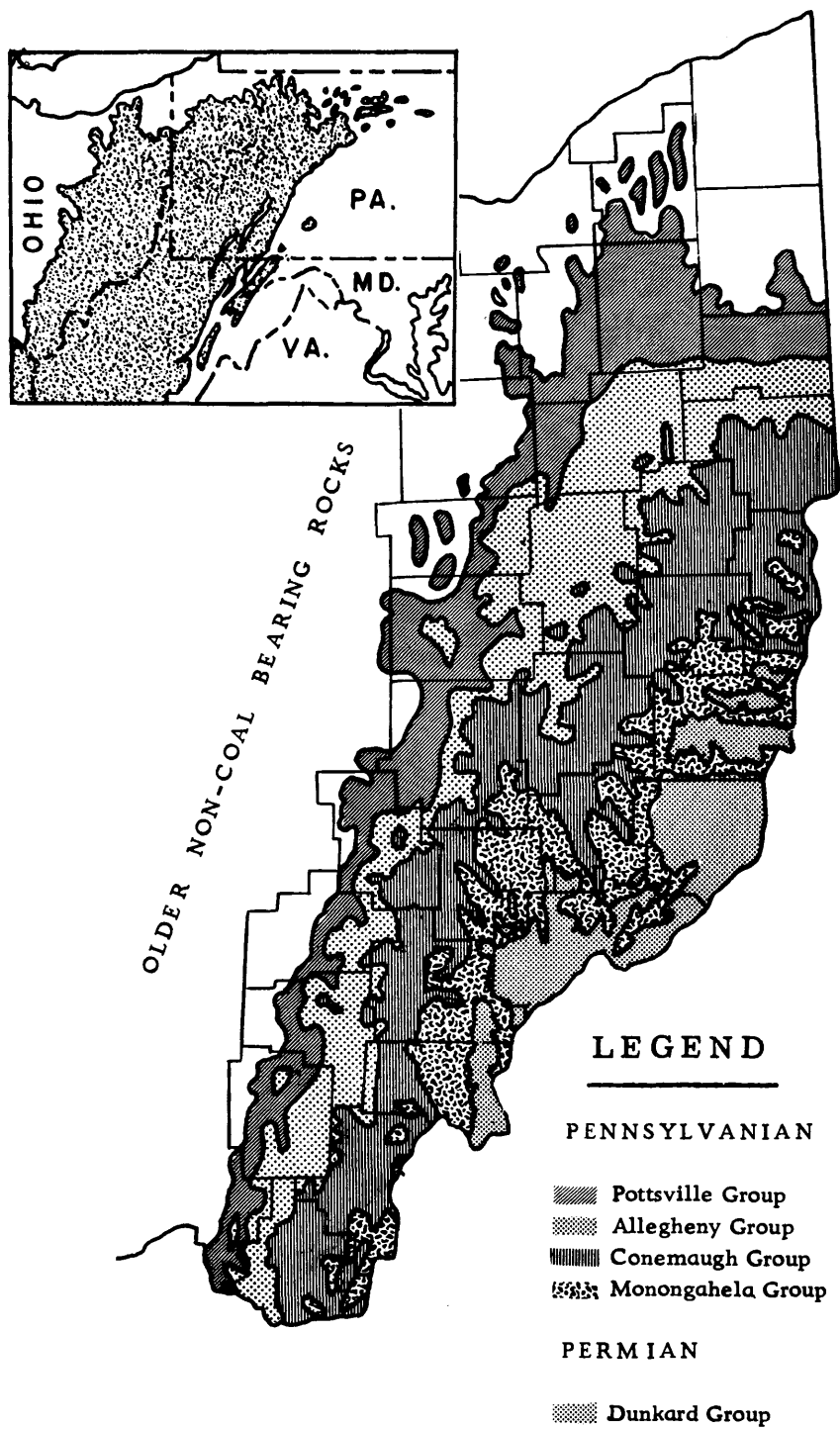


FIGURE 1. The coal-bearing groups of rocks of Ohio. The inset shows the relationship of the coal-bearing area of Ohio to the northern Appalachian coal basin.

content of coal and clay, and in places limestone. The Pennsylvanian System is divided into four subdivisions: the Pottsville Group, the basal unit, and the overlying Allegheny, Conemaugh, and Monongahela Groups. These are overlain, in turn, by Permian rocks of the Dunkard Group, which is divided into the Washington Formation below, and the Greene Formation above (fig. 2).

In Ohio these five groups contain 24 known minable coal beds. A number of the beds are traceable for great distances, but some are of only local occurrence. Coal resources in the State are distributed rather unequally among the five groups as shown by the fact that Ohio's prime coal resources are contained in only two of the groups, the Allegheny and Monongahela. The principal coal beds in the Allegheny Group are: the Brookville (No. 4), Clarion (No. 4a), Lower Kittanning (No. 5), Middle Kittanning (No. 6), Lower Freeport (No. 6a), and Upper Freeport (No. 7). The Monongahela Group contains the Pittsburgh (No. 8), Redstone (No. 8a), Sewickley or Meigs Creek (No. 9), and others of less value.

Correlation of the coal-bearing rocks, and especially the coal beds themselves from one area to another, is necessary in studying the distribution and lithologic character of these coal beds and associated strata. Many means are brought to bear in identifying and correlating a coal bed or other rock type. Criteria such as rock type and associated minerals, thickness of rocks in a coal-to-coal interval, occurrence of fossils (and now particularly, the determination of the fossil-spore content of coal beds), and topographic elevation of a coal bed must all be considered in identification and correlation. Some of the thicker coal beds, such as the Pittsburgh (No. 8) are extensive and well known. Others, as those in the Pottsville and Conemaugh Groups and minor beds in the other groups, are not so well known because they are thin, discontinuous, poorly exposed, or economically unimportant. Part of the apparent variation in the character of the coal beds and their associated rocks comes from the inaccurate correlation of strata. Intrinsic variations, however, do occur in the beds, and most characteristics involved in these variations can be geologically mapped.

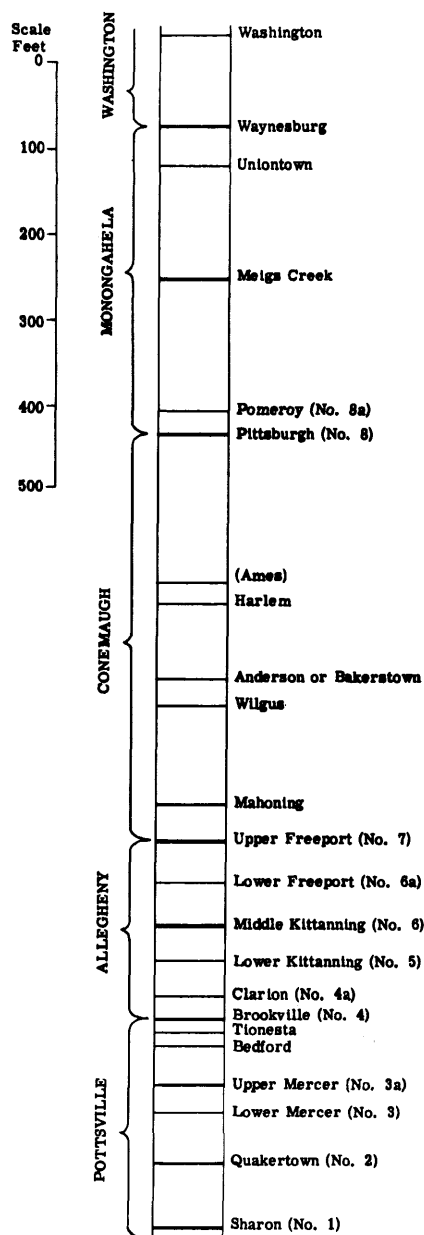
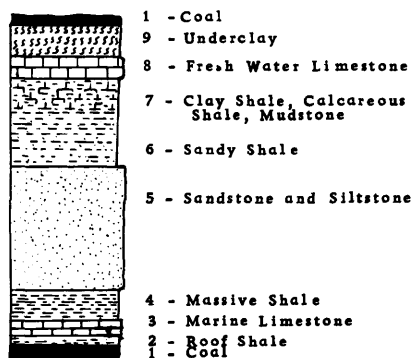


FIGURE 2. Generalized stratigraphic column showing the occurrence of the principal coal beds with respect to the geological groups in which they are found.

## ROCK SEQUENCE IN UNDISTURBED OVERBURDEN

Undisturbed overburden above the different coal beds in Ohio consists of a sequence of rock types, somewhat similar in the different coal-to-coal intervals. In an ideally complete coal-to-coal interval, nine rock types or units are present (fig. 3). Coal is the lowest unit and generally is followed in the sequence by roof shale, usually a very dark gray to black fissile shale. In part of the Pennsylvanian sequence the next rock above the roof shale is marine in origin and is often manifest as a limestone, usually very hard and weather resistant. However, this interval in some areas may be occupied by dark shale containing marine fossils. Above the marine member there is usually a shale lighter in color but very massive and blocky in its larger aspect. Sandstone is the next unit above the massive shale and may occur as a lens-like body occupying a small area, or as a widespread sheet-like body which extends for miles. Grading upward, the sandstone gives way to sandy or silty shale which may be massive or slab-like. The sandy shale or siltstone is followed in the rock sequence by clay shale, mudstone, or calcareous shale. Above this, in many areas, lies limestone of fresh-water origin, which is found at the base of overlying underclay. This limestone, in contrast to the marine limestone, has remarkable weathering characteristics in that it readily breaks down into a mass of small particles. This member is sometimes called underclay limestone. The unit above the limestone is generally clay, which in most areas under-

FIGURE 3. The relative positions of the different rock types in an idealized coal-to-coal interval. Usually two or three of the rock types are dominant in the section at any one locality. The principal concentration of pyrite is in the coal and roof shale.



lies the coal of the next higher coal-to-coal interval. Because of its location under the coal, it is called the underclay. Clays of various composition and quality occupy this position, the more useful and better known ones of which are found in the Pottsville and Allegheny Groups. The foregoing is an ideal coal-to-coal interval as it is known in Ohio, but there are only a few places where all the units of the ideal interval are present. More often than not, a strip-mine cut reveals that two or perhaps three of these rock types dominate the section.

## SUMMARY OF COAL-BEARING ROCKS IN OHIO

Rocks of the Pottsville Group contain only modest resources of coal and other minerals. However, the highest quality heating coals in Ohio have been mined from the Sharon (No. 1) and Quakertown (No. 2) coal beds, which are found near the base of the Pottsville. Quartz-sand deposits of the highest quality are also found in the Pottsville Group. Other minable coal beds in the group include the Lower Mercer, Middle Mercer, and Bedford. Most of this sequence is dominated by shale and sandstone, which is accompanied by subordinate amounts of marine limestone associated with coal zones.

Lower Pottsville sediments were laid down on a highly irregular Mississippian erosion surface, so that Lower Pottsville rocks are restricted to the ancient valley

areas. Today we find these rocks as rather scattered deposits of irregular outline. It was not until about the time of deposition of the Lower Mercer (No. 3) coal and Middle Mercer limestone that the Mississippian valleys were filled. Probably from that time on through the Pennsylvanian, sedimentation was more continuous and sheet-like over eastern Ohio. As a result of differential compaction in the sediments overlying the irregular Mississippian surface, coal beds of the Pottsville and lower Allegheny Groups are generally quite irregular or "rolly." Undulations or rolls are common in coal beds as high in the geologic column as the Middle Kittanning (No. 6) coal.

The Allegheny Group contains a wealth of coal resources, which are found in several beds. The rock types associated with these coals are several in number, and variation of these rocks over the Ohio coal region is great, although predictable. The lower part of the Allegheny contains two principal coal beds, the Brookville and the Clarion. The Brookville (No. 4) coal occurs in small deposits, particularly in northern Ohio and in a few areas in southern Ohio. The Clarion (No. 4a) coal is known to occur at minable thickness in southern Ohio. Both of these coal beds are associated with a persistent marine zone close above. In places this zone is composed entirely of shale, but in many areas it is made up of hard, weather-resistant limestone. The same relationship is true for the Clarion



FIGURE 4. View of the middle part of the Allegheny Group in the north-central part of the Ohio coal region. The bottom of the pit is on the Lower Kittanning clay bed, immediately above which lies the Lower Kittanning (No. 5) coal. A dark shale 20-ft thick overlies the coal and is capped by the Strasburg (No. 5a) coal. Dark shale grades upward to light gray shale and siltstone over the Strasburg coal. Near the top of the section the Middle Kittanning (No. 6) clay and coal lie below dark shale and buff-colored sandstone. This sequence is widespread in northern Ohio and typifies much of the Allegheny Group in the north-central portion of the State.

coal. The limestones reach substantial thicknesses in places, especially in the eastern part of the State, where the Vanport limestone is many feet thick and is mined. In the Canton area, a number of mines take the Putnam Hill limestone, which overlies the Brookville coal, and in some places the coal and limestone are mined from the same pits.

Higher in the Allegheny section, marine zones overlying the coal are manifest as fossiliferous shales and only rarely as limestone. In northern Ohio, a dark shale commonly makes up the marine zone overlying the Lower Kittanning (No. 5) coal bed. The same rock type also is generally found above this coal bed in the central-northern part of the coal-bearing area, where very few examples of limestone are to be found in the interval between the Lower Kittanning (No. 5) and Middle Kittanning (No. 6) coal beds (fig. 4). However, in the general outcrop area to the west and south, sandstone enters into this interval in greater proportion and occupies a significant part of the geologic section. The interval from the Middle Kittanning (No. 6) to Lower Freeport (No. 6a) coal beds in northern Ohio contains much shale and siltstone, as well as variable but moderate amounts of channel-fill sandstone. To the southwest the relative amount of sandstone increases, and much of the geologic section over the Middle Kittanning coal is occupied by this rock.

The first fresh-water limestone deposits in the Pennsylvanian System are found at about the stratigraphic level of the Middle Kittanning (No. 6) coal and clay. In eastern Ohio, limestone occurs at the base of the Middle Kittanning clay and is known as the Leetonia (Salem) limestone. In the interval between the Middle Kittanning (No. 6) and Lower Freeport (No. 6a) coal beds, a relatively persistent but by no means universal fresh-water limestone bed occurs under the Lower Freeport clay. It is at this horizon that a significant occurrence of fresh-water limestone may in places be found in strip mines of the State. The geologic section from the Lower Freeport (No. 6a) to Upper Freeport (No. 7) coal beds is roughly similar to the interval from the Middle Kittanning (No. 6) to the Lower Freeport (No. 6a) coal beds, with the exception that more siltstone and sandstone are found in the higher interval. Fresh-water limestones are also associated with the Upper Freeport clay, and in some areas the total thickness of such beds may be several feet. The Upper Freeport (No. 7) coal marks the top of the Allegheny Group.

The Conemaugh Group contains only a few minable coal deposits, the principal ones of which are the Mahoning, Wilgus, Anderson, and Harlem. Many other coal beds occur but are not known to be of minable thickness or significant areal extent. The Conemaugh Group contains several marine zones, of which the Ames and the Cambridge yield limestone in commercial quantities. A number of fresh-water limestone beds are also found in the group. In fact, the occurrence of fresh-water limestone below and marine limestone above the coal beds is characteristic of much of the Conemaugh. Marine limestones are not found in the upper third of the Conemaugh Group or in stratigraphically higher zones in Ohio.

The Monongehela Group is probably most notable for the Pittsburgh (No. 8) coal which forms its base. This group is characterized in eastern Ohio by a series of coal, limestone, and shale beds. To the south and southwest the limestone is replaced by sandstone and shale beds and the Pittsburgh coal becomes thin and discontinuous. For example, the interval from the Pittsburgh (No. 8) to the Sewickley (No. 9) coal bed in the Belmont County area consists of beds of coal, fresh-water limestone, shale, and small occurrences of silt or sandstone. Between the two principal coal beds, the Redstone (No. 8a) and the Fishpot coal beds are observed, but are rarely minable. To the south and west the Pittsburgh coal diminishes in thickness and takes on a much different character, as do the associated rocks. On the outer edges of the area of the Pittsburgh coal, coarse-grained siltstone and sandstone overlie the coal, and the coal takes on a highly

impure character. In this area the Pittsburgh (No. 8) coal has been confused with the stratigraphically higher Sewickley or Meigs Creek (No. 9) coal, which is known for its low purity. Farther to the south in the area of the Monongehela outcrop, sandstone makes up a substantial portion of the stratigraphic section. In all these coal beds, however, there is a persistent association of overlying roof shale and coal.

Above the Sewickley (No. 9) Coal there are few coal beds of economic value, the only ones being the Uniontown (No. 10) and Waynesburg (No. 11). The Dunkard Group contains very little coal of minable thickness or of sufficient purity to support mining. The Washington coal is the ranking coal bed in the Dunkard Group.

#### OVERBURDEN DISTURBED IN COAL MINING

In most of the areas of coal strip mining, the soil horizons are an insignificant part of the total thickness of overburden disturbed. On the northern edge of the coal-bearing area in Ohio and southward into parts of Muskingum and Perry counties, a moderately thick mantle of glacial till overlies the bedrock, and in a number of places where the coal is strip mined, a substantial part of the overburden material is composed of glacial till. This generally loose boulder clay is often referred to as soil, but in reality it is a type of parent material. Its character is somewhat variable, but in many places it is calcareous and thus, when disturbed in strip mining, may lend itself well to reclamation.

Many types of minerals have been assembled by sedimentary processes, and through various agencies these have been altered and lithified to form rocks in the form that we see them today. For the most part the rocks were formed from sediments which were laid down under chemically reducing conditions. In the petrographic examination of the Sheban core from eastern Ohio, particle counts of carbonaceous matter were nearly equivalent to particle counts of pyrite, showing a very close relationship between carbonaceous matter and pyrite or, at least, between reducing conditions and the occurrence of pyrite. At outcrops and in mines, these materials are exposed to the atmosphere and to oxidizing conditions for the first time since their deposition. The forces of the atmosphere, and the resulting oxidizing conditions, are strong and tend to disintegrate most rocks, but not at a uniform rate. Some sandstones are among the most resistant types and are the slowest rocks to disintegrate; shales and clays, on the other hand, are the least resistant and disintegrate most rapidly. Long-term weathering processes are important factors in the changes that take place in disintegrated rocks which provide parent material for soil formation.

The materials or strata making up the overburden above a coal bed, although diverse in character, are present in discrete layers. Strip mining greatly disturbs the arrangement and original relationships of these layers. For example, sandstone that in its original state was porous and may have carried water freely may in a spoil bank be distributed among shale and clay particles which fill the effective pore space in the sandstone, thus reducing the porosity and water-conducting qualities of the latter. Conversely, a shale layer may be broken part and distributed among grains or pieces of sandstone so that a greater surface of the shale is exposed to weathering and the shale is more rapidly broken down and changed. In a number of places, pyritic shales are associated with sandstone which may contain little or no pyrite. The mixing process caused by strip mining has brought the aerating qualities of sandstone into close association with the pyritic shales so that the latter can be oxidized at higher than normal rates.

Probably the most spectacular chemical weathering phenomenon evidenced in the coal-bearing rocks is the oxidation of pyrite. The resulting salts—sulphate of iron and sulphuric acid—are highly reactive and combine readily with the aluminum of the clay minerals. The effects on the character of associated materials

are profound. The net result is to release large quantities of soluble ions at very high rates. Although pyrite is geologically ubiquitous and is found in a broad variety of rock types in the Pennsylvanian geologic column, it is most common in coal and its immediately overlying strata. As a rule, each higher rock layer in a coal-to-coal interval contains smaller amounts of pyrite.

Petrographic examination of a number of cores and sections has confirmed the concentration of pyrite in the coal beds and in the beds closely overlying the coal. Since the pyrite is thus concentrated in certain beds originally, very possibly the best treatment in reclamation of spoil banks is to maintain that concentration. The more the highly pyritic rocks are returned to their former reducing environment, the less will be the amount of acid resulting from weathering of these rocks.

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